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TITLE

AN APPROACH TO THE PROBLEM OF DETERMINING PINE-BEETLE HAZARD IN PONDEROSA PINE FORESTS OF OREGON AND WASHINGTON

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Statement of Problem.

Because of the slow growth of ponderosa pine, it is generally recognized by foresters and lumbermen that it is going to be exceedingly difficult, if not impossible, to maintain continuous production in the ponderosa pine region at anywhere near the present cut. The possibility of balancing growth with drain is made even more remote as long as utilization is paralleled by bark-beetle losses, which in themselves more than offset growth.

For many years the Bureau of Entomology and Plant Quarantine has been working on the complex problem of the cause for and control of bark-beetle epidemics in the hope of answering at least three vital questions--(1) Why have beetle epidemics been so severe in recent years? (2) How can our pine stands be managed to avoid disastrous beetle epidemics? and (3) What management policy offers the greatest hope of future beetle control?

In analyzing what has happened in ponderosa pine forests of Oregon and Washington during the past two decades, one fact stands out rather clearly, i.e., that losses have not been of equal intensity throughout this region. Some areas have lost over 50 percent of their merchantable timber, while other areas, not so far away, have been only slightly affected. Why such great differences? The answer to this question may yield some important clues that are basic to the whole beetle problem. And so in the past three years an intensive analysis has been made of stand conditions and environmental and biological factors on a large series of sample plots to see if we can pin down a few of the basic causes underlying this difference in losses.

Past Studies.

Fourteen years ago Dr. Craighead[1/] reported the tentative conclusions of forest entomologists dealing with the western pine beetle problem. At that time it was recognized that losses were associated with poor site and were heaviest in stands of mature, decadent, slow-growing trees.

Studies made in 1924 by Person[2/] brought out the fact that losses were associated with open, pure pine stands along ridges or any exposed sites, and that rapidly growing pines in dense stands, especially in mixtures on north slopes or in low moist situations, such as along streams, were least attractive to the western pine beetle. Person showed losses averaging 77 trees per square mile on Site II at Cascadel in the central California Sierras, as against 156 trees on Site III and 210 trees per square mile on Site IV. He concluded, however, that site quality as such might not be the factor of importance but merely reflected the fact that the beetles preferred slow-growing trees, and that more of these were found on the poorer sites.

Subsequent studies have shown the importance of individual tree growth and vigor, and the bark-beetle susceptibility classification[3/] which has been developed as a result of these studies makes possible tree selection in view of relative bark-beetle hazard.

During the past three years the Berkeley forest insect laboratory has given special attention to the problem of recognizing the relative beetle hazard of different ponderosa pine areas. In coining

the term "hazard zonation" this laboratory has called special attention to the importance of this problem. Reports by Salman and Johnson give in considerable detail the methods which they have developed so far, and how these are now being used in northeastern California to classify forest areas as to insect hazards. In their hazard zonation work, over 1,000,000 acres have already been covered by field parties, and plans call for the expenditure of over $50,000 in this type of work.

Present Study.

With 11,000,000 acres of commercially valuable ponderosa pine in eastern Oregon and Washington, there is a similar need for the classification of areas as to relative insect hazard. Having no funds for a special field survey of hazard conditions, an attempt was made by the Portland laboratory to see what could be done, at least in a preliminary way, to determine relative hazards of different parts of the ponderosa pine region from the basic data already collected by numerous timber surveys, forest resource surveys, U. S. Geological Survey surveys, and the last three years of extensive bark-beetle surveys. The present report explains the approach to this problem of combining and analyzing existing records and the results obtained.

The objective of all of this work is first to determine what factors are of importance and can be recognized in the field as indicating beetle hazard conditions, and secondly to map in place the relative hazards of different pine areas as a basis for logging plans, forest management, or direct control action.

Area Hazard Factors and Their Importance.

The first step in determining a basis for hazard zonation is a recognition of the factors which determine hazard and an evaluation of the weight which should be given to each. Starting with a general knowledge of bark-beetle behavior over the past two decades, one can list a number of factors as warranting consideration. These fall into two groups: (1) Factors which influence beetle populations, and (2) actors affecting tree resistance.

I. Factors which influence beetle populations.

(1) Life zone—optimum life zone for western pine beetle populations. This is the composite of environmental and climatic conditions which favor the development of certain forms of life. Ponderosa pine is predominantly a Transition Zone species, but extends into the Sonoran Zone in its lower limits and into the Canadian Zone at its upper limits. The western pine beetle follows the range of its host tree, but finds Canadian Zone conditions distinctly unfavorable for its activity.

The average level of life zones is fairly constant, but from year to year, depending upon seasonal climatic conditions, there may be a raising or lowering of the altitudinal and latitudinal limits. When this occurs, the trees cannot move but the beetles do. The result is that losses at the higher levels in the Canadian Zone only

occur in seasons when Transition Zone conditions have been temporarily raised. In general, therefore, the Canadian Zone is the least hazardous, Transition Zone of average hazard, and Sonoran Zone of greatest hazard.

(2) Elevation.—ranging from about 3,500 to 7,000 feet. Because of its relation to life zones, elevation is an important index to beetle hazard, although in itself having no direct influence on beetle abundance or tree resistance.

(3) Temperature—frequency of low winter temperature and length of growing season. Our studies have shown that the western pine beetle cannot thrive in areas where the usual winter temperatures drop below -20°F, or where developmental temperatures during the summer make for a short growing season. Temperature is an important constituent of life zones and in a large measure determines why life zones influence beetle risk.

(4) Past losses.—varying from less than 5 percent of the total stand to over 60 percent of the stand killed in the last two decades. The fact that past losses have been heavy or light on a given area is the best possible index of what the hazard factors have been. Since many hazard factors change but slowly, past losses are also a valuable clue as to where future losses will probably occur, provided of course, that the losses themselves have not materially changed conditions.

In areas where recent losses have been heavy, conditions are obviously favorable to beetle development and populations are likely to be high. On the other hand, if stands have been badly depleted by past epidemics, only the more resistant types of trees remain, and future losses must decline. Such a condition now prevails on most of the poor sites surrounding the Sprague River Valley.

change in risk of old trees on poor sites

Where light losses have occurred, conditions have been unfavorable for the beetles and will probably continue to be so over a long period of time unless abruptly changed by fires, drought, or other disturbances.

II. <u>Factors affecting tree resistance.</u>

(5) <u>Growth rate</u>—both normal growth and the change in growth rate must be considered. The growth rate of trees on any area not only indicates their individual age and vigor, but reflects all of the environmental conditions which affect them. It is the best measurable index of beetle hazard, since it is a composite index of so many factors affecting both the tree and the beetles.

As trees become adjusted to their environment, normal tree growth responds accordingly. This may be either high or low, depending upon whether or not the site is favorable, the age and vigor of the tree, and the degree of tree competition. If normal tree growth represents a balance between all of these factors, as it usually does,

it has little or no significance to beetle damage, except indirectly in indicating where the greatest change in growth may occur.

When the stand is in balance, any decrease in stand vigor due to drought or other causes is reflected in a reduction of growth rate. As growth rate declines, a state of unbalance occurs and beetle damage increases to relieve the pressure. The greater the reduction in growth, the greater the beetle loss. This relationship has been shown by the correlation analysis to be the most significant of any of those analyzed. Moreover, it is perfectly logical that this should be the case. As long as all environmental conditions remain static, the stand is in balance. As soon as that balance is disturbed, losses occur. By examining the other factor, however, we may be able to predict where conditions of unbalance are most likely to occur.

(6) Forest type—whether pure pine or in mixture with juniper, incense cedar, or fir. The association of various tree species is an excellent index to life zone and growth conditions, and so indirectly is of value in indicating relative hazard to beetle attack.

Biological races of P. pond. adapted to different environments.

On the drier sites, where ponderosa pine and juniper are found in association, there is only a narrow margin of safety in available moisture. Dry years quickly reduce this below the minimum requirements for ponderosa pine growth and thus produce favorable conditions for beetle damage.

Mixed stands of white fir and pine indicate better moisture conditions (which in these types is usually more than ample to provide for ponderosa pine requirements), and critical reductions in growth rate are not so quickly brought about during drought periods. These types are less susceptible to beetle damage.

Stands with lodgepole pine in mixture with ponderosa pine indicate colder conditions, which are decidedly unfavorable to beetle activity.

(7) Site quality--running in this region from II to VI. The fertility and productive capacity of any given area of forest land is referred to by foresters as site. In the ponderosa pine region, site quality is measured by the height of 10 percent of the tallest trees. It is obvious that site represents a combination of many factors affecting tree health and is an important index in determining hazard to beetle attack.

Site II represents the best sites found in Oregon or Washington, and stands of this site quality, with dominant trees 150 to 175 feet in height, are found in certain portions of the Pokegama Plateau west of Klamath Falls, Oregon.

The poorest sites, with dominant trees less than 75 feet in height, are found along the timber margins usually at low elevations. But poor sites may also be found at more northern latitudes and at high elevations near timberline.

Because site is associated with changes in growth rate, it is a valuable index to beetle hazard, but in itself holds no significance. Stands may become adjusted to poor sites just as well as to good sites, and it is only when changes come about that poor sites may suffer more than good ones.

(8) Stand volume—varying from less than 1 Mbm to over 30 Mbm per acre. The volume of a stand reflects the fertility of the soil, site, type, and other conditions related to growth rate. Except for its relation to growth rate, stand volume as such shows no significance as a beetle hazard factor. Heavy volumes are usually associated with good sites, mixed types, and high growth rate, and are therefore low beetle risks; and the reverse is usually true but not necessarily

so, for a light stand may be due to thinning by a forest fire, or previous heavy beetle losses, and will show light losses in the near future.

(9) Stand structure—the proportion of different age and vigor classes in the stand, and proportion of susceptible trees. The composition of a stand, particularly the proportion of trees of different ages, degrees of vigor, and susceptibility to beetle attack, determines in a large measure its chances of suffering from bark-beetle damage, provided other conditions favor development of beetle populations. Young, second-growth stands, with a preponderance of age classes 1 and 2 and crown classes A and B[3] are relatively immune to beetle damage; while old, overmature stands of high quality slow-growing timber are of high risk.

Of course, the fact that some stands have reached an old age and now contain a high proportion of overmature, decadent, highly-susceptible trees is in itself evidence that these stands must have been relatively free from beetle activity for a considerable period of time, but it does not necessarily follow that they will continue to be immune, or on the other hand that they are now due to suffer heavy losses. Perhaps they are above the zone of aggressive beetle attack or are in a cold area where beetle damage is consistently light.

Stand structure is an important factor which must be taken into consideration in rating the hazard of stands, but must be modified by other considerations which may take precedence over it.

(10) Fire history--this factor involves time since last fire and how heavy previous burns have been. Fire is an agency which can quickly change the beetle hazard rating of an area. If the trees are badly scorched and partially defoliated, the first effect is to reduce the growth rate and increase the beetle damage, as studies by Miller and Patterson have shown.[4] Trees which survive the fire and subsequent beetle outbreak gradually build back their foliage and increase their growth rate. This may take 10 years in severely burned areas. Then if competition of neighboring trees and brush has been eliminated by the fire, the period of reduced growth is usually followed by a period of accelerated growth, increased tree vigor, and a corresponding reduction in beetle damage.

Thus we have a period of high hazard immediately following fires, which gradually returns to normal at the end of about 10 years, then a period of low hazard for about 10 years which gradually increases as ground cover builds back and competition increases.

The severity of the fire and the amount of vegetation destroyed is also a consideration. The heavier the burn and the more competition is removed, the lower the beetle hazard will be after recovery. Light ground fires seem to have very little influence one way or the other, and a burn has to be heavy in order to have an appreciable effect on subsequent beetle damage. For this reason it can hardly be recommended as a profitable form of beetle control.

Weight to be Given to Each Factor. While it is not so difficult to show significance or lack of significance for single independent factors, it is much more difficult to determine their relative importance and what part each plays in the common association with all the others. In fact, the problem is so complicated that it can only be solved a little at a time.

Recently an analysis was made to determine the correlation between beetle damage and some of the important variables encountered in ponderosa pine stands. Records from annual cruises made by the Bureau of Entomology and Plant Quarantine on 25 full-section sample plots in the Klamath Basin during the 10-year period 1921 to 1930, inclusive, furnished the basis for this analysis.

The average percent of ponderosa pine stand killed per year, which varied from .79 percent to 5.94 percent, was correlated with the following four independent variables: (1) Site index, (2) volume of pine per acre, (3) volume of annual growth, and

(4) percent reduction in growth rate from normal. Of these four variables, the only one that was found to be directly associated with beetle loss was percent reduction in growth rate from normal. The other factors were found to be only indirectly associated with beetle loss.

In other words, any ponderosa pine forest, whether on good or poor site, if growing at a normal rate, is adjusted to its environmental and climatic zone and will not suffer from abnormal beetle loss unless something happens to reduce its growth rate. But if weakened by drought or other causes, it will become susceptible to beetle damage, and the damage which follows will be in proportion to such weakening. Growth rate is the most tangible and easily measured index to those conditions which influence the health and vigor of a forest stand, but is not in itself the cause of beetle depredations.

As yet, correlation studies with other hazard factors have not been made, and so it is impossible at this time to say just how much weight should be attached to each. This one study, however, gives us a clue as to what to expect. It is obvious that no environmental condition can have a permanently hazardous influence, for if it did, ponderosa pine stands would never have been able to grow there in the first place or survive through the ages. The hazard of beetle damage must be related to factors which fluctuate over a period of time. Where such fluctuations are most apt to occur may be anticipated by studying present stand conditions, particularly as to whether or not such stands are in a state of unbalance and growth rates reduced below normal trends.

A Method of Combining Hazard Factors.

Since forest surveys have already accumulated a great deal of detailed information on a number of these beetle hazard factors, it is possible to construct a hazard map by combining this information and thus show in place the areas of greatest beetle hazard. As a preliminary step, maps were prepared covering the ponderosa pine forests of the Klamath and Deschutes Subregions, combining a number of the above hazard factors, for which information was already available. The Forest Resource Survey's type map, on a 1/4-inch-to-the-mile scale, was used as a base. On an overlay sheet each hazard factor was indicated by a given cross-hatch symbol, running from light to heavy lines, depending on the degree of hazard. It was possible by this means to combine the following factors and show them in place.

(a) Forest type--from data obtained by the Forest Resource Survey and shown on their lithographed and 1-inch-to-the-mile forest maps.

(1) Very low hazard. Types 20B and 27#--upper slope types with less than 50 percent by volume of pine in mixture with fir; type 22--young growing stands less than 12 inches in diameter; type 34 (22)--cut-over stands, 80 percent or more of the volume removed; type 38--badly fire-killed or bug-killed areas with insufficient mature timber left to sustain an epidemic.

\# See footnote on page 15.

(2) Low hazard. Types 20 and 20A—mixed types with 50 to 80 percent by volume of pine in mixture with fir, or lodgepole; type 21—young growing stands 12 to 22 inches in diameter, selectively cut stands with 40 to 60 percent of stand removed, and fire-killed or bug-killed areas with some mature timber left.

(3) Medium conditions. Type 20.5—pure ponderosa pine type with 80 percent or more of pine.

(4) High hazard. Type 20.5—pure ponderosa pine type in association with juniper.

(5) Very high hazard. Type 5½—scattered woodland or "fringe" type.

(b) Site quality—from site maps prepared by the Forest Resource Survey on 1/4-inch-to-the-mile scale.

(1) Very low hazard—Sites II and III+.

(2) Low hazard—Sites III and III-.

(3) Medium condition—Sites IV+ and IV.

(4) High hazard—Sites IV- and V.

(5) Very high hazard—Sites V- and VI.

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* Type numbers used by Forest Resource Survey are described in Forest Research Notes No. 25, Feb. 5, 1938, "Forest Statistics for Eastern Oregon and Eastern Washington" issued by the Pacific Northwest Forest and Range Experiment Station.

(c) Elevation—from U. S. Geological Survey contour maps and state contour maps now being prepared by the Forest Service Office of Maps and Surveys.

Because life zones change not only with elevation but also with latitude and longitude more or less in conformity with Hopkins law (4 days later for each 1° of latitude northward, 5° of longitude eastward, and 400 feet of altitude upward), elevations were corrected so that each elevational zone would represent the same relative plant zone in different parts of the region. At Klamath Falls, Oreg., (Lat. 42° N., Long. 122°) the following elevational zones were used:

(1) Very low hazard—above 6,500 feet elevation.

(2) Low hazard—5,500 to 6,500 feet.

(3) Medium condition (the range of the pure pine type)—4,500 to 5,500 feet.

(4) High hazard—3,500 to 4,500 feet.

(5) Very high hazard—below 3,500 feet.

(d) Volume of ponderosa pine stand per acre—data from Forest Service timber surveys and Forest Resource Survey compilations, showing volume of stand section by section.

(1) Very low hazard—20 Mbm per acre or over.

(2) Low hazard—15 to 20 Mbm per acre.

(3) Medium condition—10 to 15 Mbm per acre.

(4) High hazard—5 to 10 Mbm per acre.

(5) Very high hazard—less than 5 Mbm per acre.

All four of these factors express in different ways much the same thing—the optimum growth conditions for pine, the medium condition, and poor conditions. In addition, elevation, because of its relationship to temperature and length of growing season, probably has some more or less direct influence upon the abundance of beetle populations.

It would have been advantageous to have included other important hazard factors such as growth rate, percentage of susceptible trees in the stand, distribution of low temperatures, and the location of old forest fires. While these data were available for many sample plots distributed throughout the region, no interpolation between plots was possible. These factors can only be obtained in sufficient detail by very intensive field surveys made expressly for such purpose.

Since all of these factors could not be combined on one overlay sheet without considerable confusion in drafting, the work was done in steps. The first overlay combined forest type and site quality. The results for a section of the Sprague River Valley in Klamath County are shown in figure 1.

A second overlay combined timber stand and elevation. This combination for the same area as in figure 1 is shown in figure 2.

By putting these two overlays together over a light table, the combination of the four factors showed gradations of shading from light to heavy. A negative made from this combination and printed on a blue-line print gave the results shown in figure 3. This might be considered as the theoretical picture of hazardous conditions, assuming that the four factors used were all of importance.

In actual practice, instead of using five gradations of shading as was necessary in order to make the blue-line prints of figures 1, 2, and 3, the two low hazard conditions were shown in two weights of black lines, the medium condition was left blank, and the two high hazard conditions were shown in two weights of red lines. This brought out an intensification of black in areas where all factors combined to show low hazard and an intensification of red in the high hazard areas.

The next step was the preparation of another overlay map, entirely independent of the first set, and showing in place the distribution and intensity of past beetle damage as determined from three years of regional bark-beetle surveys and Forest Service check cruises. Three years of mapping the intensity of bark-beetle losses,

each year's map being prepared by different survey crews and based on strip and plot work, have served to give a detailed and consistent picture of the distribution of losses. Combining all the evidence available, the loss map was prepared on the basis of showing the average gross percent of stand killed per year during the last 10 to 15 years. A sample of this map, for the same area as shown in figures 1 to 3, is given in figure 4.

On comparing figure 3, which shows the theoretical hazards based on forest conditions, with figure 4, which shows the actual losses which took place in the last 10 to 15 years, a very close agreement will be noted. It is evident that the four factors combined in figure 3 serve to explain rather fully why losses occurred where they did. This agreement undoubtedly would have been improved if other hazard factors could have been included, particularly reduction in growth rate and temperature; but even so, the evidence is sufficient to give a useful, preliminary indication of the relative hazards of different areas.

On comparing the loss map, figure 4, with the preliminary overlays shown in figures 1 and 2, it is evident that the best agreement is between figure 2 and figure 4. In other words, timber stand and elevation show a closer agreement with the distribution of losses than do forest type and site, although these two factors also follow the same general pattern.

Future Hazard Map. The third and final step consisted of combining the two overlay maps, as represented by figures 3 and 4, to construct a third map showing future hazard. This step, involving a jump from actual forest conditions and past losses to a prediction of what the future holds in store for these forest stands, necessarily required the making of certain assumptions. These assumptions, which may or may not be entirely valid, were as follows:

(1) For the next 10 years, the bark-beetle hazard to ponderosa pine stands will not be radically different from that prevailing during the past decade, except that

(2) As stands become badly depleted through repeated beetle attack, there will be a gradual shift of losses into stands at higher elevations and of lower hazard rating, which still provide overmature, highly susceptible trees.

(3) Stands which have been badly depleted and now show improved growth rate of the surviving stand and a recent reduction in loss rate can be given a lower hazard rating because they no longer contain sufficient volume of susceptible host material to support an epidemic. In extreme cases, such stands fall in the same category as cut-over or badly fire-killed areas.

With these assumptions in mind, and with plot evidence as to present growth rates and loss trends, the two overlay maps illustrated by figures 3 and 4 were combined to give a map of estimated future hazard, illustrated by figure 5.

Five Future Hazard Classes Defined.

For convenience, five degrees of hazard were recognized—very low, low, medium, high, and very high hazard. Any other division of relative hazard might have been made, but this gave two degrees of low hazard, the medium condition, and two degrees of high hazard, which is as close a division as the information would warrant making, and as close as is needed by forest owners in making general logging or management plans. These hazard classes were defined as follows:

(1) Very low hazard—cut-over, burned, or badly bug-killed areas, or young stands where appreciable net growth can be expected.

(2) Low hazard—thrifty mature stands where losses and growth are approximately in balance, probable gross loss in a 10-year period not exceeding 7 percent of the volume of the stand.

(3) Medium condition—mature to overmature stands where losses exceed growth by a small margin, depleting mature stand over a natural rotation of about 300 years, probable gross loss varying between 8 and 15 percent of stand in a 10-year period.

(4) High hazard—overmature stands where losses are approximately double the growth rate, probable gross loss between 15 and 20 percent of the volume of the stand in 10 years.

(5) Very high hazard—overmature, decadent stands where losses are more than double the growth rate and rapidly depleting the reserve, probable gross losses exceeding 20 percent of the volume in 10 years.

Using this system of hazard rating and the information available from bark-beetle surveys and forest statistics, preliminary hazard maps have been prepared covering over 3,000,000 acres of ponderosa pine forests in the Klamath and Deschutes Subregions. These maps are to be included in reports covering each subregion and will be issued separately.

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Legend for
Figure 1
Forest Type and Site Quality

Forest Type

Very low hazard. Types 20B and 27--upper slope types with less than 50% by volume of pine in mixture with fir; Type 22--young growing stands less than 12 inches in diameter; Type 34 (22)--cut-over stands, 80% or more of the volume removed; Type 38--badly fire-killed or bug-killed areas with insufficient mature timber left to sustain an epidemic.

Low hazard. Types 20 and 20A--mixed types with 50 to 80% by volume of pine in mixture with fir, or lodgepole; Type 21--young growing stands 12 to 22 inches in diameter; Type 34 (21)--selectively-cut stands with 40 to 60% of the stand removed; fire-killed or bug-killed areas with some mature timber left.

Medium condition. Type 20.5--pure ponderosa pine type with 80% or more of pine.

High hazard. Type 20.5--pure ponderosa pine type in association with juniper.

Very high hazard. Type $5\frac{1}{2}$---scattered woodland or "fringe" type.

Site Quality

Very low hazard--Sites II and III+

Low hazard--Sites III and III-

Medium condition--Sites IV+ and IV

High hazard--Sites IV- and V

Very high hazard--Sites V- and VI

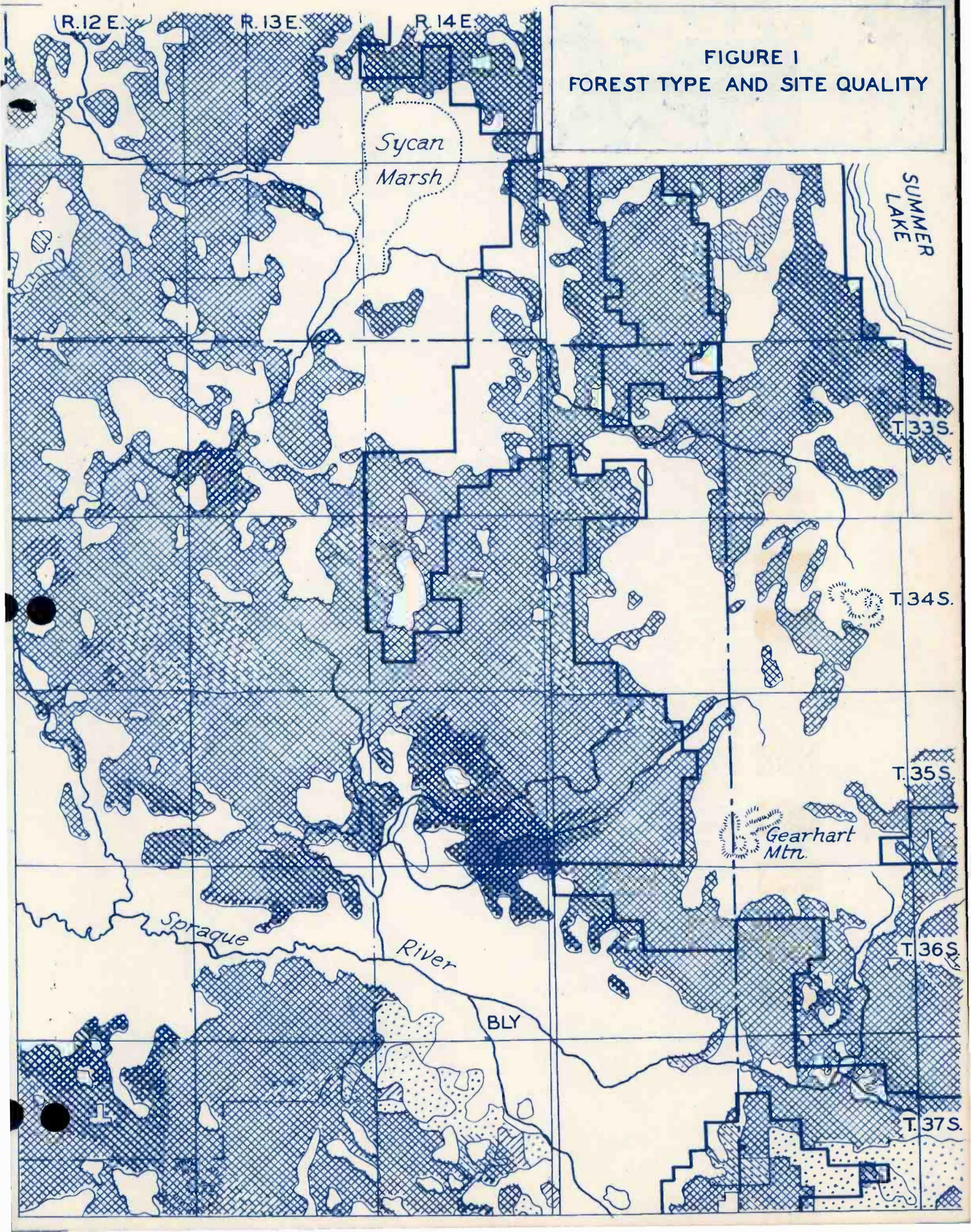


FIGURE I
FOREST TYPE AND SITE QUALITY

LEGEND FOR
FIGURE 2

TIMBER STAND AND ELEVATION

Timber Stand

 Very low hazard—20 Mbm per acre and over.

 Low hazard—15 to 20 Mbm per acre.

 Medium condition—10 to 15 Mbm per acre.

 High hazard—5 to 10 Mbm per acre.

 Very high hazard--less than 5 Mbm per acre.

Elevation (Lat. 42°, Long. 122°)

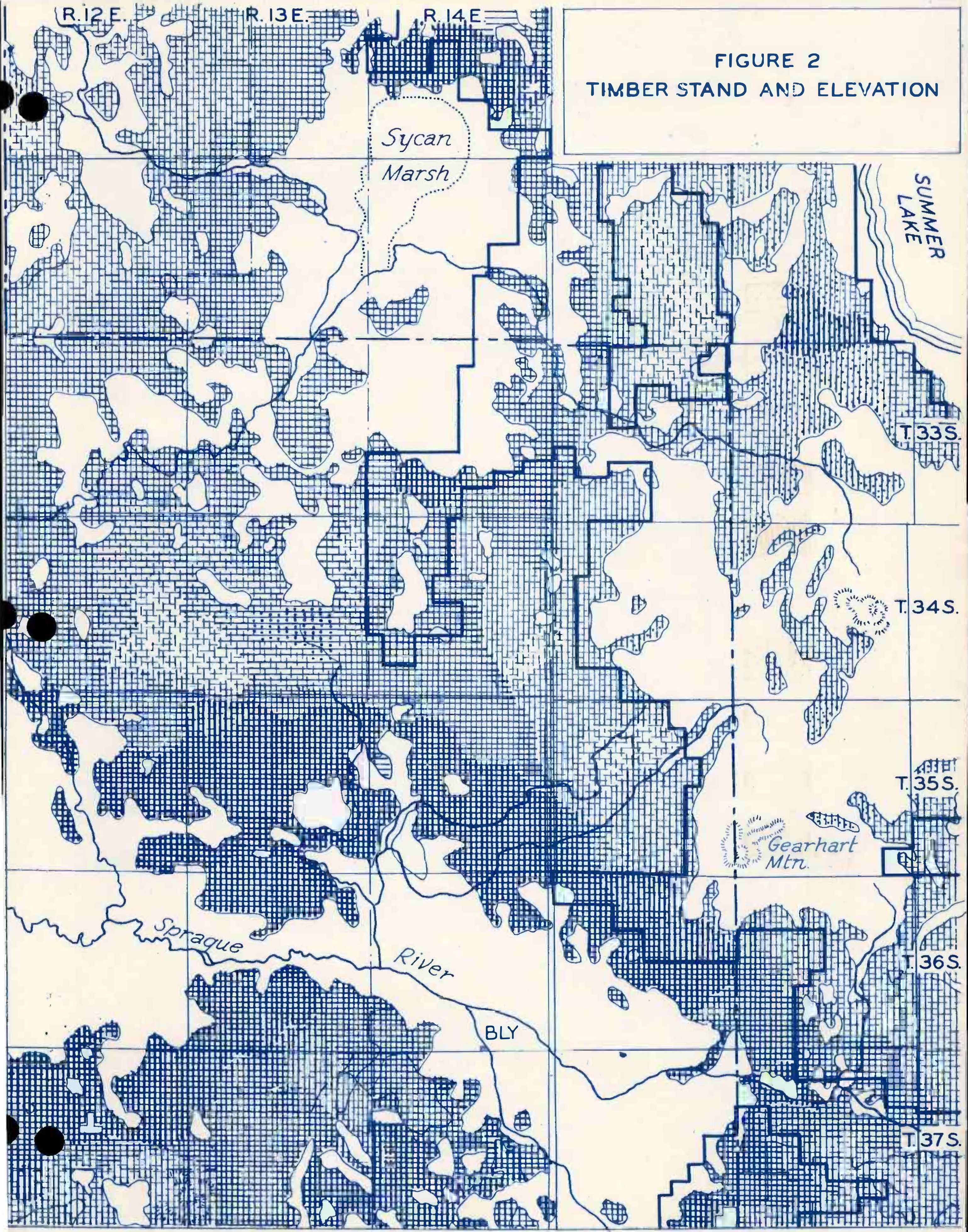
 Very low hazard--above 6,500 feet.

 Low hazard--5,500 to 6,500 feet.

 Medium condition—4,500 to 5,500 feet.

 High hazard--less than 4,500 feet.

FIGURE 2
TIMBER STAND AND ELEVATION



LEGEND FOR
FIGURE 3

COMBINED STAND CONDITIONS

This map obtained by printing Figures 1 and 2 together.

The light shading indicates low hazard.

The heavy shading indicates high hazard.

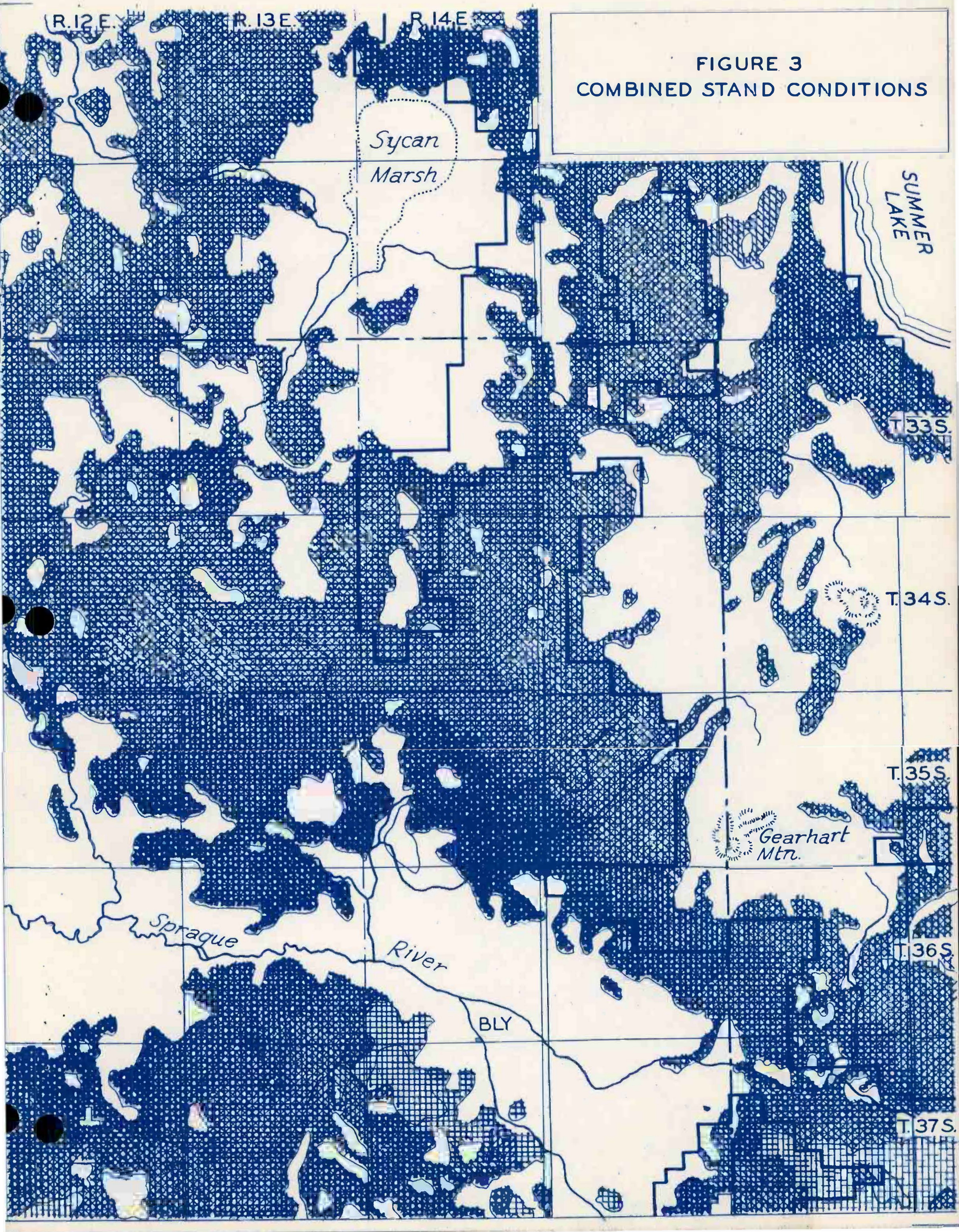


FIGURE 3
COMBINED STAND CONDITIONS

LEGEND FOR
FIGURE 4

ACTUAL PINE BEETLE LOSSES

This map combines all available information on distribution of pine beetle losses during the past 10 to 20 years.

Cut-over lands and burns with little or no mature timber left.

Normal infestation—.0 to .5% of stand volume per year.

Light epidemic—.6 to 1.0% of stand volume per year.

Moderate epidemic—1.1 to 2.0% of stand volume per year.

Heavy epidemic—2.1 to 3.0% of stand volume per year.

Very heavy epidemic—3.1% and over of stand volume per year.

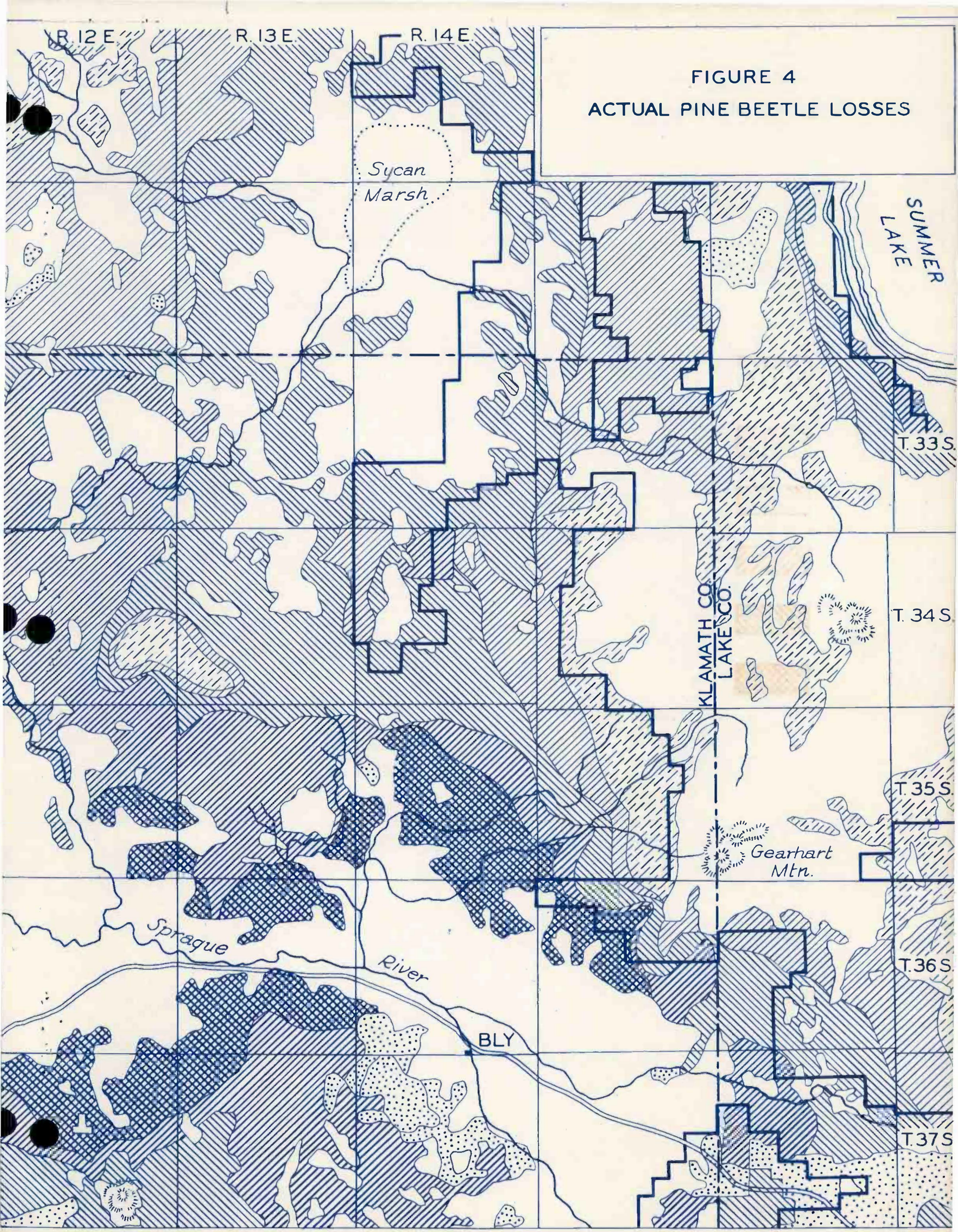


FIGURE 4
ACTUAL PINE BEETLE LOSSES
R.12 E.
R.13 E.
R.14 E.
Sycan Marsh
SUMMER LAKE
T.33 S.
T.34 S.
T.35 S.
T.36 S.
T.37 S.
KLAMATH CO.
LAKE CO.
Gearhart Mtn.
Sprague River
BLY

LEGEND FOR
FIGURE 5

ESTIMATED PINE BEETLE HAZARD

Very low hazard. Cut-over, burned, or badly bug-killed areas.

Low hazard. Probable loss from 0 to 7% in 10 years.

Moderate hazard. Probable loss from 8 to 15% in 10 years.

High hazard. Probable loss from 15 to 20% in 10 years.

Very high hazard. Probable loss 20% and over in 10 years.

Non-timbered areas.

National Forest boundary.

Scale 1 inch = 4 miles.

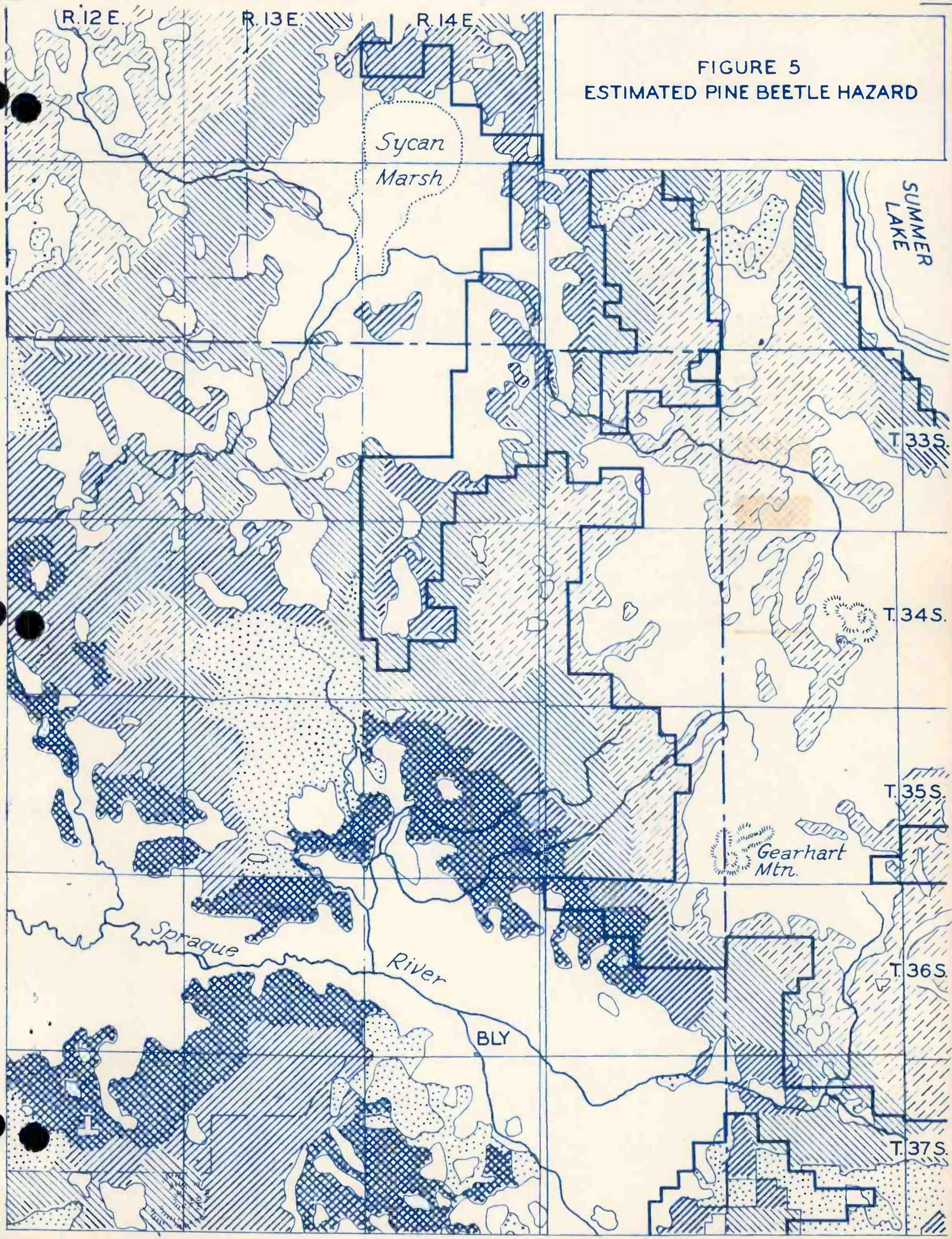


FIGURE 5
ESTIMATED PINE BEETLE HAZARD
R.12 E.
R.13 E.
R.14 E.
Sycan Marsh
SUMMER LAKE
T. 33 S.
T. 34 S.
T. 35 S.
Gearhart Mtn.
T. 36 S.
Sprague River
BLY
T. 37 S.